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Report on the Progress of Regulations to Protect Stratospheric Ozone

Report to Congress
August 1979

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16. ABSTRACT

This report reviews the progress made by EPA from March 1978 to August 1979 in regulating ozone depleting substances. In March 1978 EPA along with Food and Drug Administration (FDA) issued final rules prohibiting the manufacturing and processing of chlorofluorocarbons (CFCs) for non-essential aerosol propellant uses. EPA continues its investigation of nonaerosol and miscellaneous CFC uses, including use as refrigerants, foam blowing agents, cleaning agents in the electronic and metal industries and as solvents. The EPA study includes several regulatory strategies to reduce CFC emissions, namely, 1) direct regulation, 2) economic incentives and 3) a conservation program. Because CFC emissions in any country may have adverse effects globally, the reduction of CFC emissions is an international concern. EPA is developing programs to investigate other substances or chemicals that may deplete the stratospheric ozone. In implementing the Clean Air Act and deciding whether and to what extent further regulation is necessary, EPA is continuing its studies of current developments in ozone processes, of adverse health and environmental consequences of ozone depletion, of technological capability to reduce emissions from major sources, and of the cost of achieving control.

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REPORT ON THE PROGRESS
OF
REGULATIONS TO PROTECT
STRATOSPHERIC OZONE

REPORT TO CONGRESS

AUGUST 1979

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OFFICE OF TOXIC SUBSTANCES
401 M Street, S.W.
Washington, D.C. 20460

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WASHINGTON, D.C. 20460

THE ADMINISTRATOR

The Environmental Protection Agency transmits its report on regulatory actions to protect the stratospheric ozone in accordance with Section 155 of the Clean Air Act Amendments of 1977 (Public Law 95-95).

Douglas M. Costle

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SUMMARY

As mandated by Section 155 of the Clean Air Act Amendments of 1977, PL 95-95 (CAA), the Environmental Protection Agency (EPA) submits to Congress this report on the progress of regulation to protect the stratospheric ozone. By doing this, EPA fulfills the requirement that a final report be prepared within two years of legislative enactment of the CAA. As directed, subsequent follow-up reports on actions to protect stratospheric ozone will be prepared annually.

This report summarizes the final action taken against the use of chlorofluorocarbons (CFCs) as propellants in aerosol products. Because regulatory development had begun under the Toxic Substances Control Act (TSCA) before the CAA was passed, EPA promulgated the CFC aerosol ban regulation under Section 6 of TSCA.

This report also outlines the current investigation of nonaerosol uses of CFCs, the status of international cooperation to control CFCs, and the evaluation of other possible ozone depleting substances. If EPA finds that there is a need to require control of CFC emissions from nonaerosol uses, EPA will use the authority of Section 155 of the Clean Air Act.

Together with the Food and Drug Administration (FDA), EPA issued final rules prohibiting the manufacturing and processing of CFCs for nonessential aerosol propellant uses in March 1978. EPA and FDA based this action on the theory, supported by laboratory determined reaction rates and ambient measurements of CFC and other reaction species, that CFCs may deplete the ozone layer that shields the earth's surface from harmful ultraviolet radiation emanating from the sun. Scientific evidence shows that increased exposure to short wavelength ultraviolet radiation can harm human health and the environment.

The EPA rule (referred to as Phase I) covers all aerosol propellant uses except uses in food, drugs, medical devices, and cosmetics which are covered under the FDA regulation. The Consumer Product Safety Commission (CPSC) played a major role in supporting the EPA and FDA regulations. However, CPSC chose not to issue a separate regulation, since most uses under its jurisdiction were covered under the EPA and/or FDA regulations.

The Phase II investigation of nonaerosol and miscellaneous uses is currently underway. This is primarily directed toward nonaerosol categories of CFCs, including refrigerants for refrigeration and air conditioning units, foam blowing agents in the manufacture of foams, cleaning agents in the electronic and metal industries, freezing agents for foods, and solvents. Annual emissions from the manufacture and use of U.S. nonaerosol products containing CFCs are estimated to be about 300 million pounds for 1976/77, and the total is expected to about double by 1990, although the rate of increase may vary for different categories of use.

A phenomenon called "banking", connected with certain products using CFCs appears to be growing. The CFC bank represents CFCs that remain or are stored in products such as insulating foams and air conditioners and will be released slowly to the atmosphere during normal use or disposal of the product. Emissions from banked products can vary widely depending upon the product. Preliminary estimates indicate that the quantity of banked CFCs, about 675 million pounds in 1976/77, is expected to increase annually at a rate of about 160 million pounds per year, to over 2 billion pounds by 1990.

Phase II studies also include evaluation of a host of miscellaneous aerosol products which use CFCs as active ingredients instead of as propelling agents. These products, excluded from the aerosol ban regulation by definition, emit small quantities of CFCs ranging from several thousand to over a million pounds per year.

EPA is awaiting the release of several key reports: the National Academy of Sciences' updated report on the chemistry and physics relating to stratospheric ozone depletion by CFCs, resulting effects to life on earth of decreased stratospheric ozone, and alternative control technology; the Rand Corporation's final report on the economic feasibility of controlling nonaerosol uses; SRI International's risk/benefit analysis; the University of Maryland's cost/benefit analysis; and our own assessment of the risk to health and the environment from continued use of CFCs. These reports will be used by EPA to support its decision of whether or not to regulate. In the meantime, EPA is investigating several regulatory strategies to reduce CFC emissions. Currently under consideration are 1) direct regulation; 2) economic incentive approaches to pollution abatement; and 3) a conservation program relying on industry cooperation. These three options are not mutually exclusive and could be used in combination to maximize net social benefit.

In addition to the Phase II investigation, the Office of Air Quality Planning and Standards is currently developing regulations which will lead to a reduction in the emissions of volatile organic compounds, including CFC-113, from organic solvent cleaning operations which include vapor phase degreasing and cold cleaning. The potential for depletion of stratospheric ozone is the basis for designating CFC-113 as one of the solvents covered by this rulemaking.

Because CFC emissions in any country are distributed globally throughout the atmosphere, the regulation of CFCs is an international problem. Representatives from the United States, 13 foreign countries, and three international organizations met in Munich in December 1978 to discuss the latest scientific and regulatory approaches to protect the ozone layer. Following the U.S. lead, a few nations indicated that they are issuing rules to prohibit nonessential uses of CFCs as aerosol propellants. However, there were many more nations who questioned scientific predictions of ozone depletion and the need for restrictive

action. Although they made no quantitative commitments to reduce CFC use or emissions, the participants did agree to make significant reductions in aerosol use from 1975 base levels. Further reductions will be made if supported by new evidence. EPA will continue to encourage other nations to reduce, and eventually eliminate, CFC emissions from nonessential aerosol uses.

Investigations into other substances or chemicals that may deplete the ozone are moving ahead. The Office of Toxic Substances (OTS) has developed preliminary plans to screen chemicals for their ozone depleting potential, as part of the ongoing risk assessment of toxic chemicals. Screening criteria will also be applied to new chemicals reported under Section 5 of TSCA, and to existing chemicals recommended for EPA review through established channels (e.g., the Interagency Testing Committee) to identify those substances which may affect the chemical and radiative balance in the stratosphere. Moreover, plans for monitoring activities are underway in OTS to systematically collect global data and prepare materials balances of chemicals suspected of depleting the ozone layer.

In implementing the CAA, and in deciding to what extent further regulation is necessary, EPA is continuing its studies and requests for studies by other Federal departments and agencies of current developments in ozone processes, of adverse health and environmental consequences of ozone depletion, of technological capability to reduce emissions from major sources, and of the costs of achieving control. A decision to propose additional regulation would be based on an evaluation of all these factors, as well as on the advantages and disadvantages of controlling nonaerosol emissions in the United States in the absence of meaningful actions to restrict either aerosol or nonaerosol emissions in other countries. Based on the findings of this investigation of nonaerosol uses of CFCs, EPA anticipates deciding in early 1980 whether or not to proceed with initiation of regulation.

I CHLOROFLUOROCARBON AEROSOL BAN REGULATION

A. The Problem

Chlorofluorocarbon molecules consist of one or more carbon atoms with chlorine and fluorine atoms attached. When released through normal use they remain stable in the troposphere and over many decades slowly rise from the troposphere into the stratosphere. Here CFCs photochemically decompose, liberating chlorine atoms. Ozone molecules react with the chlorine and are reduced to molecular oxygen. The decreased ozone concentration permits more ultraviolet radiation with wavelengths between 290 and 320 nanometers (UV-B) to penetrate to the earth, resulting in adverse health and environmental consequences.

In September 1976 the National Academy of Sciences (NAS) estimated a 7 percent (with a possible range from 2 to 20 percent) reduction in stratospheric ozone, at equilibrium, due to CFCs.[1] In a September 1977 report of a workshop sponsored by the National Aeronautics and Space Administration (NASA), expert scientists predicted a 10 to 16 percent reduction as the most probable value.[2] A later NAS report, prepared in response to Section 153(d) of the CAA, supported the NASA finding that the expected ozone reduction at equilibrium by CFC emissions is roughly double that predicted in September 1976.[3]

The latest, and to date the largest, estimated stratospheric ozone depletion due to CFCs, predicted by the Model Predictions Group at a recent NASA workshop, is about 18 percent (with a possible range between 5 percent and 30 percent).[4] This equilibrium depletion would be achieved by about the year 2050. All of these ozone depletion values are based on the assumption that CFC emissions remain constant at 1975 worldwide release rates of 750 metric tons per year.

Most scientists agree that there is a correlation between skin cancer incidence and UV-B exposure. Both the fatal but rare malignant melanoma and the more frequent but usually non-lethal

nonmelanoma skin cancer may be caused by exposure of the human skin to UV-B radiation. In addition, increased incidence of sunburn (erythema) can also be expected from UV-B exposure.

Previous studies reported that a two percent increase in nonmelanoma skin cancer occurs from a two percent increase in UV-B resulting from a one percent depletion of ozone, assuming all other factors (e.g., lifestyle, ethnic makeup) remain constant.[1] More recent analyses project increases in nonmelanoma skin cancers to be four percent for a two percent increase in UV-B.[5] Thus, current estimates of an 18 percent ozone depletion, at equilibrium, would indicate a 72 percent increase in nonmelanoma skin cancers. White-skinned people who spend more time outdoors have a much greater incidence of skin cancer, most frequently occurring on those body parts habitually exposed to sunlight.

It is also believed that increased UV-B leads to an increased incidence of melanoma skin cancer. This cancer accounts for about 2 percent of skin cancer cases and about one-half of these are fatal. The quantitative uncertainties of skin cancer predictions are expected to be reduced in the next several years by conducting more detailed epidemiological studies and more accurate measurements of UV-B on exposed areas of the skin of various population cohorts.

Enhanced UV-B radiation flux has been shown to adversely affect growth and production of certain plants and animals.[6] Terrestial plants show damage when exposed to more UV-B in the laboratory. However, the presence of visible radiation in natural sunlight may induce photorepair or some other adaptive mechanism to mitigate UV-B damage. Some aquatic animal and plant species living near the water surface appear to be very sensitive to UV-B for at least part of their life cycle. Climatic effects due to ozone depletion and increased CFC burden in the atmosphere are anticipated, but are not quantifiable nor measurable at present.

As with skin cancers, research on UV-B effects on biological and climatic systems is currently being conducted to quantitatively assess adverse impacts and to reduce remaining uncertainties. Although aware of the quantitative uncertainties in these various findings, EPA and other Federal agencies have initiated regulatory action to protect the ozone layer from adverse substances, especially nonessential uses of CFCs.

B. The Regulation

The first report to Congress dated, March 14, 1978 and required under Section 155 of the CAA, described actions taken by EPA and other Federal agencies to regulate sources of halocarbons or more specifically, chlorofluoroalkanes (CFCs).[7] The 1978 report discussed key research documents that supported the proposed rule published in May 1977. This chapter will report on the final rule published in 1978.

During the initial stages of regulatory development, EPA with assistance from other key Federal agencies, formed an interagency work group.* An EPA-approved development plan outlined the ground rules for the work group, and among other things, provided for regulating CFCs in a two-phased effort.[8] Phase I concentrated on the regulation of aerosol products using CFCs as an aerosol propellant and the promulgation of the current aerosol ban regulation.

Most of the comments received by EPA on the proposed aerosol ban rule indicated that either there was no basis to determine

*The interagency work group was formed during the Fall of 1976 when it became clear that EPA, FDA, and CPSC had begun regulatory activities on regulating CFCs. Along with members from the three agencies, representatives from the National Aeronautics and Space Administration (NASA), Department of Transportation (DOT), Department of Commerce (DOC), National Science Foundation (NSF), and the Council on Environmental Quality (CEQ) were invited to participate. Because of the recent passage of the TSCA with its broad authority, EPA was chosen as the lead agency. This work group had primary responsibility for developing the regulation.

that release of CFCs presented an unreasonable risk or that there was time to delay the proposed rule. Specifically, the public argued that

1. because of a voluntary reduction of CFCs in aerosol propellants, there no longer was a need to regulate,

2. uncertainties about the ozone depletion estimates were unresolved,

3. more time was needed for research on alternative propellants,

4. modeling studies to determine if ozone depletion has occurred had not been validated,

5. a delay in regulating would not result in adverse health and environmental consequences from continued use of CFCs as propellants, and

6. only after scientists address the inadequacies of present theories (NAS predicted two years would be adequate time) should selective regulation proceed.

After evaluating these and other comments, including scientific and economic reports, EPA and FDA concluded that despite the uncertainties in the magnitude of ozone depletion, there existed an unreasonable risk to health and the environment, if emissions from the use of aerosol products containing CFCs as aerosol propellants were allowed to continue. Data from the scientific community indicated that a decrease in the ozone concentration in the stratosphere and a resultant increase in ultraviolet radiation at the earth's surface could 1) increase the incidence of melanoma and nonmelanoma skin cancer, 2) damage ecological systems, and 3) produce climatic perturbations.

The final EPA and FDA chlorofluorocarbon aerosol regulations were published on March 17, 1978.[9,10] At that time CPSC announced that its own banning action was unnecessary, given the EPA and FDA regulations, and given that TSCA and the Federal Food, Drug, and Cosmetic Act (FFDCA) together had sufficient authority to control those products under CPSC's jurisdiction. Under the TSCA, the final EPA rule prohibited

1. The manufacture of fully halogenated chlorofluoroalkanes for nonessential aerosol propellant uses after October 15, 1978,

2. The processing and distribution in commerce of fully halogenated chlorofluoroalkanes for nonessential aerosol propellant uses after December 15, 1978,

3. The processing for export of fully halogenated chlorofluoroalkanes for nonessential aerosol propellant uses after December 15, 1978, and

4. The importation of fully halogenated chlorofluoroalkanes as a chemical substance or as part of an article for any nonessential aerosol propellant use after December 15, 1978.

Under the FFDCA the final FDA regulation[11] prohibited

1. The manufacture or packaging of food, drug, medical device, or cosmetic products containing fully halogenated chlorofluoroalkanes as an aerosol propellant after December 15, 1978, and

2. The initial introduction into interstate commerce of finished food, drug, device, or cosmetic products after April 15, 1979.

These regulations primarily affected four commercially used compounds, namely, CFC-11 (F-11), CFC-12 (F-12), CFC-114 (F-114), and CFC-115 (F-115).*

Comments received during the review of the proposed rule in the Spring of 1977 included requests from many companies for exemptions for their products from the proposed CFC rule. The interagency work group developed the criteria used to evaluate these requests. The criteria guidelines included 1) the availability of substitutes; 2) the economic significance of the product, including the economic effects of removing the product from the market place; 3) the environmental and health impacts of the product and its substitutes; and 4) the effects on the quality of life resulting from no longer having the product or a reasonable substitute available.[12] Each product for which an essential use exemption was requested was judged by these criteria. EPA and FDA then determined that certain aerosol products would be exempted in both the EPA and FDA regulations. The EPA regulation exempted

1. mercaptan stench warning devices (an odor-warning device used to alert coal miners of a pending danger),

2. release agent for molds used in the production of plastic and elastomeric materials,

3. flying insect pesticides used in nonresidential food handling areas and for space spraying of aircraft,

4. diamond grit spray,

*The letters F (referring to Freon, a duPont trade name), R, and CFC all refer to chlorofluorocarbons. In the refigeration industry, the letter R refers to refrigerant.

5. nonconsumer articles used as cleaner solvents, lubricants, or coatings for electrical or electronic equipment,

6. articles necessary for safe maintenance and operation of aircraft, and

7. uses essential to the military preparedness of the United States as determined by the Administrator of EPA and the Secretary of Defense.[9]

The FDA regulation exempted

1. metered-dose steroid human drugs for nasal inhalation,

2. metered-dose steroid human drugs for oral inhalation,

3. metered-dose adrenergic bronchodilator human drugs for oral inhalation,

4. contraceptive vaginal foams for human use, and

5. metered-dose ergotamine tartrate drug products administered by oral inhalation for use in humans.[11]

In 1975, U.S. aerosols (511 million pounds) accounted for about one half of U.S. production (1060 million pounds) and less than one quarter of total world production (about 2300 million pounds) of CFCs.[13] The U.S. used (and presumably emitted) slightly less CFCs both for aerosols and nonaerosols than the rest of the world. The U.S. regulation of aerosols was therefore estimated to eliminate more than one-half of total U.S. emissions and a little more than one-quarter of world emissions (very roughly 1700 million pounds, about equally divided between the U.S. and

the rest of the world).* Remaining U.S. CFC production was expected to be marketed almost entirely for nonaerosol uses, with the exempted aerosol uses estimated to account for two to three percent of the total U.S. CFC aerosol use.

The EPA rule was estimated to have an economic impact ranging from 169 million to 267 million dollars annually for the four years following publication of the rule.[14] Approximately 2,000 jobs were estimated to be lost in the filling, valve, and container segments of the aerosol industry. Because other types of propellants were less expensive, consumers were estimated to save 58 million to 240 million dollars annually by buying substitute products during the same four-year period. With the exception of the filling segment of the aerosol industry, the impact on small businesses was expected to be minimal, since there were likely to be some positive effects on small businesses that produced and marketed alternatives to chlorofluorocarbon products.

At the time of the publication of the EPA rule, there were six manufacturers of CFCs in the United States. Five companies (DuPont, Allied, Kaiser, Pennwalt, and Union Carbide) are large, diverse firms capable of adapting to the rule with very little effect on their profits. The smallest firm, Raycon, manufactured only CFCs, but stated at that time that it produced none for propellant uses. Thus, EPA concluded that the regulation of aerosols would not have a major effect on these firms. Since that time Union Carbide has ceased its production of CFCs.

The economic report indicated that most marketers, container manufacturers, and valve suppliers could adapt to this rule, since they were large outfits with significant aerosol volumes in other than the affected product areas. Container manufacturers and valve suppliers were both found to produce products that

* This estimate assumes that all aerosol production was promptly emitted. The study revealed that much of the nonaerosol production is retained in the product for many years.

could handle the conversion to alternative products without any costly effects. Conversion to mechanical delivery systems would possibly benefit the small firms that produce these systems.

The adverse impact on small businesses using CFCs was estimated to fall most heavily on the filler segment of the industry. One-half of the total number of fillers in the United States manufacture less than 10 million units a year, and in aggregate account for 6 percent of total aerosol filling. These fillers must convert production equipment in order to use hydrocarbon propellants, the most likely replacement for CFCs. This is largely because of the precautions necessary to handle the more flammable hydrocarbons. Since small firms have limited capital resources necessary for conversion and research and development, the impact on small filler businesses was likely to be more severe than on larger firms.

Because EPA was concerned about the impact of this rule on small businesses, EPA chose an 18 month phase-out schedule instead of an immediate ban, to minimize the economic impact on all sectors of the industry.[9,10] EPA noted that even before the rule was published, many businesses had already switched to other propellants or products. According to an industry source, by the spring of 1978 over 80 percent of products previously using chlorofluorocarbons as a propellant had switched to non-fluorocarbon propellants or finger activated pumps.[15] Figures from the Can Manufacturers Institute showed that although aerosol can shipments were 7 percent behind 1977 during the first quarter of 1978, by the end of September 1978 aerosol shipments were running about 5 percent ahead of the 1977 figures.[16] EPA concludes that this continued demand for aerosol cans during the third quarter of 1978 indicates that marketers had successfully converted to substitute propellants.

Even though EPA and FDA continue to receive requests for exemptions to the regulations, to the best of our knowledge, the impact of this regulation on American businesses does not appear to be greater than anticipated. Currently, EPA is in the process of reviewing contractor proposals to undertake a retrospective economic study of the actual economic impacts associated with the aerosol ban rule. We anticipate that this contract will be negotiated by November 1979.

C. Export Notification

On June 7, 1978, EPA published interim procedures covering notification for export of polychlorinated biphenyls and fully halogenated chlorofluoroalkanes.[17] As required by Section 12(b) of TSCA, individuals must notify EPA if they export or intend to export chemicals subject to proposed or final actions under Section 6 of TSCA. Exporters of these chemicals will notify EPA of the dates of each shipment, the country to which the chemicals are being exported, and related information. EPA in turn will notify the importing countries of the fact of export. Currently, EPA is developing permanent procedures applicable to all chemicals subject to actions under TSCA. EPA intends to propose these procedures later this year.

D. Amendments to the Rule

Since the publication of the rule, EPA continues to receive and review requests for exemptions and clarifications of the rule. One minor notice corrected the format of the rule to conform with requirements of the Code of Federal Regulations.[18] EPA published an important clarification statement on November 27, 1978.[19] The notice states that the definition of "aerosol propellant" covers not only CFCs which directly expel active ingredients but also CFCs which modify the expelling force to achieve the propelling effect in the desired manner. Vapor pressure depressant, flame retardant, and solvent uses may be "aerosol propellant" uses.

The pesticide essential use exemption was modified to permit application by metered value and total release devices. [20] Special exemptions are proposed for manufacturers of pyrethrin pesticide formulations[21] and inkless fingerprinting systems. [22] Another exemption proposes to exclude spinnerette release agents from inclusion in the original mold release agent category.[23] Other requests are under review.

II INVESTIGATION INTO NONAEROSOL USES OF CHLOROFLUOROCARBONS

A. Industrial Use Profiles

As part of Phase II of the chlorofluorocarbon (CFC) program, EPA is investigating ways to further reduce CFC emissions in the United States. EPA is examining all uses of CFCs not covered under the Phase I rule to determine where feasible controls may be possible.

EPA and FDA held two public meetings, the first in October 1977 and the second in February 1978, to obtain information from industry and other interested parties about nonaerosol uses of CFCs. The following is a summary of preliminary findings from these meetings and from reports by the Rand Corporation (Rand), E.I. duPont deNemours & Co., Inc. (DuPont), SRI International (SRII), and others.

The following lists the major uses of CFCs in the United States in terms of both quantity of CFCs used and quantity of CFCs emitted:

1. Solvents used for cleaning and drying.

2. Blowing agents for manufacturing urethane and nonurethane foam for various products including packaging materials, insulation, and furniture.

3. Heat transfer medium (refrigerant).

    a) Mobile air conditioners.

    b) Refrigerators and freezers.

    c) Centrifugal and reciprocating chillers or air conditioners.

4. Direct contact freezing agent in liquid fast freezing applications.

5. Diluent gas in sterilizing applications.

6. Active agent in fire extinguishing applications (bromofluorocarbons*).

7. Miscellaneous uses.

These uses of CFCs can be divided into two groups, prompt emitters and nonprompt emitters. Prompt emitters are defined as products which emit all CFCs within one year, either during manufacturing or immediately upon use. Prompt emitters include solvents used for cleaning and drying; blowing agents for flexible urethane foams and nonurethane packaging foams; direct contact freezing agent in liquid fast freezing; and diluent gas in sterilizing applications.

Nonprompt emitters retain CFCs over a long period of time. Although some emissions occur during the manufacturing process itself, manufacturing emissions for most nonprompt emitters represent a small portion of total CFCs used. The remaining CFCs, not emitted during manufacturing, become part of what is referred to as the CFC bank. The CFC bank represents CFCs that are stored in products such as air conditioners and insulating foams and are emitted slowly during the normal use or disposal of the product.

For example, a nonprompt emitter such as an insulating foam may contain a total of one pound of CFCs, but it may take many years of normal product use for these CFCs to be emitted to the atmosphere. Disposal emissions occur when a product reaches the

* Although not included in Phase I, bromine compounds such as Halon 1301 are included in Phase II because they have been identified as potential ozone depleters in Section 153 (a) of the Clean Air Act.

end of its useful life, and is disposed of before emitting all of its CFCs. All or part of the remaining CFCs may be emitted at that time.

Emissions from the CFC bank play an important role in estimates of future emissions. Rand estimates that without controls the CFC bank will grow from approximately 670 million pounds in 1976 to 2100 million pounds in 1990. Nonprompt emitters contributing to the CFC bank include blowing agents for rigid urethane insulating foams; refrigerants in mobile air conditioners, refrigeraters, freezers, and chillers; and active agents in fire extinguishing applications (bromofluorocarbons).

During the course of this investigation, EPA, CPSC, FDA and the interagency work group have been collecting information on current and predicted demand for CFCs, the amount of CFCs emitted from each use, the value of each use, and the cost of reducing emissions from each use. (See Table 1 for a summary of CFC emission estimates.) This information will be analyzed in conjunction with a theoretical damage function based on predicted levels of ozone depletion caused by estimated levels of CFC emissions. The cost of reducing emissions will be balanced against the benefits of decreased damage.

Since virtually all CFCs used today are eventually emitted to the atmosphere, EPA has been seeking ways that producers and users of CFCs can reduce emissions. An overall reduction in emissions through substitution or recovery and recycle will reduce demand for CFCs. Reduced demand for CFCs may adversely affect the markets for some related chemicals such as those used in the production of CFCs or produced as by-products of the CFC production process.[24] Any of these effects will be included in the cost of regulation.

Table 1

SUMMARY OF ESTIMATES OF USE, EMISSION, AND BANKING OF CFCS FOR NONAEROSOL APPLICATIONS*
(million of pounds)

CFC Application	1976/1977 Used	1976/1977 Emitted	1990 Used	1990 Emitted	1976 Banking	1990 Banking
Solvents (CFC-113)	65	65	200	200	0	0
Urethane Flexible Foams (CFC-11)	35	35	59-98	59-98	0	0
Nonurethane Packaging Foams (CFC-11, 12, 113, 114, 115)	24	24	65	65	0	0
Insulating Foams (CFC-11)	58	20	236	85	230	1400
Mobile Air Conditioners (CFC-12)	96	83	131	128	220	380
Chillers (CFC-11, 12, 114, 502)	?	14	?	20	60	90
Fire Extinguishers (Halon 1301)	2	<1	?	<2	6	35
Liquid Fast Freezing	6	6	18	18	0	0
Sterilization (CFC-12)	12	12	?	?	0	0
Totals	(298)	278	(709-748)	(601-640)	666	2100

*All estimates are from preliminary reports by the Rand Corporation.

The following is a summary of emission reduction strategies identified by the EPA:

1. Modify current technology.
   a) Improve design to reduce CFC emmissions.
   b) Substitute another substance for CFCs.
   c) Improve operating procedures.

2. Recover and recycle used CFCs during normal use and at disposal.

3. Destroy CFCs at disposal.

4. Ban the use of CFCs.

These strategies are being reviewed in Phase II to determine their application to the various CFC uses. Below is a summary of progress to date.

1. Solvents

CFC solvents are used by some 2000 plants as industrial cleaning and drying agents. The primary user is the electronics industry. Approximately 65 million pounds of CFC-113 solvent (which account for over 90 percent of all CFC solvent sales), were used and promptly emitted in 1977.[26] The use of CFC-113 as a solvent may triple to nearly 200 million pounds by 1990.[25]

DuPont estimates that emissions can be reduced 35 to 50 percent through equipment redesign and recycling of waste. These modifications are estimated to be cost effective at current prices. However, in preliminary reports The Rand Corporation warns that by improving equipment efficiency, the cost of using CFC-113 as a solvent may decrease relative to other solvents thereby increasing the use and emissions of CFC-113.[25] EPA is evaluating substitutes as well as strategies for reducing overall emissions from solvent uses.

In the area of vapor phase degreasing and cold cleaning, regulatory efforts are currently underway by the Office of Air Quality Planning and Standards which will result in a reduction of approximately 64% in the emissions of solvents used in these applications. The emission standards, developed under Section 111 of the CAA, will apply equipment, design, work practice, and operational standards to limit emissions of volatile organic chemicals (VOC) including CFC-113 and other non-CFC solvents from cleaning operations which use cold cleaners, open top vapor degreasers, and conveyorized degreasers.

2. Blowing Agents

CFCs are used as blowing agents in three types of foam products: urethane flexible foams, nonurethane (packaging) foams, and urethane rigid (insulating) foams. Blowing agents give the foams certain performance characteristics. The flexible urethane foams and nonurethane packaging foams require CFCs for soft resiliency. The rigid urethane insulating foams contain CFCs as the insulating medium.

CFCs are released at different stages in the manufacture and use of each of the three types of foam. During the manufacture of flexible, open-cell urethane foam, CFCs are released into the atmosphere almost immediately. The CFCs pass through the product because the cells are open. On the other hand, CFCs slowly diffuse out of rigid insulating foams during their normal use, and must be considered as part of the CFC bank. Approximately 40 percent of the CFCs used in manufacturing nonurethane packaging foams are retained in the foams but are generally released within a year upon disposal of the product. For the purpose of estimating total emissions, packaging foams will be considered prompt emitters.

a) Flexible Foams

Flexible urethane foam is used in furniture, automobiles,

and carpeting. CFC-11 is used as a blowing agent in approximately one-third of all flexible foams, with the remaining foam being blown with carbon dioxide, water, or methylene chloride. In 1977 35 million pounds of CFC-11 were used for this purpose, and Rand predicts that without controls use will grow to between 59 and 98 million pounds annually by 1990.[26] Since flexible foams are prompt emitters, the amount of CFC-11 predicted to be used in a year is also predicted to be emitted in that same year.

Two methods for reducing emissions are substitution, and recovery and recycle. Less expensive methylene chloride can be substituted for 75 percent of overall CFC-11 use. In the past the use of methylene chloride as a blowing agent was limited because it could cause the foam to collapse.[26] Recent technological advancements are believed to alleviate this problem.[26] If methylene chloride is found to be environmentally acceptable, it could be used as a substitute for CFC-11 in most flexible foams. However, methylene chloride is currently on EPA's list of toxic pollutants under Section 307(a) of the Clean Water Act of 1977, and is being investigated for toxicity, degradability, persistence in water, and other criteria listed under Section 307.

Recovery and recycle may be feasible for applications for which methylene chloride cannot be used as a substitute. Carbon adsorption beds may be used to recover the CFCs for future recycling. However, this technology requires further study.

b) Nonurethane Packaging Foams

Approximately 24 million pounds of CFCs were used as a blowing agent in the production of packaging foams in 1977. These products, made of extruded polystyrene sheet, polyolefin, expanded polystyrene, and polyurethane, include stock trays, egg cartons and single service food containers for the fast food industry. The principal CFC blowing agent is CFC-12, although

CFC-11, CFC-113, CFC-114, and CFC-115 are also used in small quantities. Rand predicts that without controls, annual CFC consumption for this industry will climb to approximately 65 million pounds by 1990.[27]

CFC recovery is a potential, yet untested technological method of reducing emissions from packaging foams.[27] Since the exact nature of emissions from these foams is not known, it is impossible to predict the emissions reduction attainable through recovery. Although available data suggest a maximum possible recovery of 60 percent, evaluation of applicable control technology is needed in this area.

A substantial portion of packaging foam, especially extruded polystyrene sheet, is pentane blown. However, pentane does pose a serious fire hazard. Paper, on the other hand, may be the safest and cheapest substitute for CFC blown packaging foam.

c) Rigid Urethane Insulating Foams

Insulating foams such as rigid urethane foams and extruded polystyrene board required 58 million pounds of CFCs for manufacturing in 1977, primarily CFC-11. Because of the rapidly growing demand for insulation, CFC consumption in this category is expected to quadruple to approximately 236 million pounds by 1990. This insulation is widely used in both the residential and commercial construction industries.

Unlike the flexible and packaging foams discussed above, rigid foams retain the CFCs used in production for many years. Since CFCs function as a better insulating medium than air, the more CFCs that are retained, the better the insulating qualities of the foam. Only about 15 percent of the CFCs used is emitted during the manufacturing process. Emissions in 1977 are estimated to have been approximately 20 million pounds. Rand predicts annual emissions to increase to approximately 85 million pounds annually by 1990, taking into account the gradual release of CFCs from foams in use and a 50 percent release of the CFCs remaining at the time of disposal of the foams.

All the CFCs that have been used in the production of insulating foam, but have not been emitted, are part of the CFC bank. The amount of banked CFCs from insulating foams alone is expected to grow to approximately 1.4 billion pounds by 1990.[25] With this amount of CFCs stored away in the insulation of buildings, refrigerators, and freezers, annual emissions would eventually double even if insulation production ceased to expand in 1990.[25]

We have not yet identified an emissions control strategy for insulating foams. Little is known about the rate of CFC emissions and the amount of CFCs remaining in the foam at the time of disposal. Therefore, it is difficult to estimate the amount of CFCs recoverable at the time of product disposal.

3. Heat Transfer Medium (Refrigerants)

CFCs are used extensively as refrigerants in mobile or automobile air conditioners, refrigerators, freezers, and chillers (stationary air conditioners). It is estimated that approximately 115 million pounds of chlorofluorocarbon refrigerants were emitted in 1976. Over 80 percent of these emissions were from mobile air conditioners. Rand predicts CFC refrigerant emissions to increase to over 170 million pounds annually by 1990.

All the refrigerant uses are similar in that a significant portion of refrigerant inside each unit is held within the product for many years and becomes part of the CFC bank. Air conditioners, refrigerators, and freezers are estimated to have accounted for 430 million pounds of the CFC bank in 1976 and may account for as much as 670 million pounds by 1990. Mobile air conditioners account for over 50 percent of these banked CFCs.

a) Mobile Air Conditioners

Mobile air conditioners emitted an estimated 83 million pounds of CFC-12 in 1976. Seventy-four percent of all

automobiles manufactured in the United States in 1976 came equipped with air conditioners, up from 7 percent in 1960.[25] Each air conditioned car is charged with between 2 and 5 pounds of CFCs. Air conditioners installed as original equipment in U.S. cars average approximately 3.8 pounds per unit. Rand predicts continued growth in the mobile air conditioner market and estimates 1990 emissions to be as high as 128 million pounds of CFC refrigerant.

CFC emissions from mobile air conditioners are divided into six separate categories: 1) manufacture; 2) leakage; 3) recharge; 4) service; 5) accidents; and 6) disposal. Leakage and service (other than recharge) account for over 50 percent of emissions. Disposal emissions are expected to increase from 10 percent in 1976 to 19 percent of total emissions by 1990.[25] This increase is due to the expected growth in disposal of cars equipped with mobile air conditioners. Manufacturing emissions are expected to decline because of improved work practices; recharge emissions may grow slightly. Accident emissions will probably remain a small category. Table 2 summarizes these emission estimates.

Table 2

Estimate of Most Likely Emissions From Mobile Air Conditioners[28]

(thousands of pounds per year of CFC)

	1976	1990
Manufacturing	14,600	11,300
Leakage (normal use)	22,800	36,300
Service	28,000	43,200
Recharge	3,300	4,700
Accident	5,400	8,400
Disposal	8,500	24,900
Total	82,600	128,800
CFC Cumulative Bank from 1960.	222,000	383,500

Rand has identified three major emission reduction strategies. First, redesigning mobile air conditioners to eliminate leaking would reduce emissions by at least 25 percent.[25] Second, a change in servicing and recharging procedures could result in emission reductions of over 25 percent. Currently CFCs are released into the atmosphere during servicing. However, techniques to recover and recycle used CFCs during servicing are being developed.[29]

The third strategy is to recover used CFCs at time of disposal. This recovery could yield a significant reduction in lifecycle emissions. By 1990, disposal emissions may be a significant part of total mobile air conditioner CFC emissions. However, it is uncertain how much of the CFC charge remains in the air conditioner at the time of disposal. Technology must be developed to economically recover, refine, and recycle the used CFCs. A system of incentives such as rebates, deposits, or bounties may be needed to make CFC recovery from automobiles attractive.

EPA is currently investigating a mobile air conditioner that uses air as its primary refrigerant and may use a non-chlorofluorocarbon as its secondary refrigerant. If this system is found to be technically feasible and economically competitive, it would substantially reduce future annual CFC emissions.

b) Refrigerators and Freezers

1. Retail Food Store Refrigeration Systems

Currently, some 183,000 retail food stores have food refrigeration systems. CFC emissions from these systems were about 13 million pounds of CFC-12 in 1976, and are anticipated to grow to 15 million pounds by 1990. Annual emissions are expected to increase only slightly, since manufacturers are switching to

CFC-502 which is 48.8 percent CFC-22 * and 51.2 percent CFC-115. By 1990, at the current rate of conversion, CFC-502 will grow from 33 to 67 percent of the total refrigerant stock in retail food store refrigeration systems. However, even assuming this rate of conversion, the amount of CFCs banked in these products is expected to grow from 55.5 million pounds in 1976 to approximately 81 million pounds in 1990.

Approximately 70 percent of retail food store refrigeration and freezer emissions result from maintenance and leakage. Since CFC-502 costs nearly three times as much as CFC-12, there is a strong economic incentive to reduce these refrigerant losses. Investigation along these lines is only now beginning. One promising method of leak detection involves the use of a red dye. This dye, when mixed with the refrigerant, will make currently undetectable leaks easily identifiable.

2. Home Freezers and Refrigerators

Home freezers and refrigerators accounted for a small fraction of the annual CFC refrigerant emissions. Estimated annual CFC-12 emissions are 4.9 million pounds in 1976 and 7.3 million pounds in 1990. The amount of CFCs remaining in these products, however, is expected to grow from 96 million pounds in 1976 to 117 million pounds in 1990 as the number of home freezers and refrigerators increases.

The major source of emissions from home units is equipment disposal. Rand reports that control of emissions at disposal would require that small quantities of refrigerant be collected at several million separate locations. The cost of collection, reprocessing, and redistribution would greatly exceed the value of the recovered CFC.[30] The only other emission reduction option currently under consideration is a switch to CFC-22 which is currently used in window air conditioning units.

* CFC-22 is not fully halogenated chlorofluoroalkane and therefore is not subject to either Phase I or Phase II regulation. The potential of CFC-22 as an ozone depleter is now being investigated.

c) Centrifugal and Reciprocating Chillers (air conditioners)

In 1976 an estimated 43,000 large centrifugal chillers, air conditioners which are used primarily in large buildings, emitted a total of 12.2 million pounds of CFCs. In the same year approximately 125,000 smaller reciprocating chillers, air conditioners which are used primarily in homes, emitted only 2.4 million pounds of CFCs.

An estimated 90 percent of newly installed reciprocating chillers use CFC-22. Thus, CFC emissions from reciprocating chillers should be negligible by 1990. However, CFC emissions from centrifugal chillers are expected to increase to 20 million pounds annually by 1990.[31] The amount of CFCs banked in centrifugal and reciprocating chillers is expected to grow from 60 million pounds in 1976 to 90 million pounds by 1990.

In 1976, 80 percent of chiller emissions were caused by leaking and servicing; this is expected to fall to 68 percent by 1990. Because of the rising cost of refrigerant, the centrifugal chiller manufacturers are trying to reduce emissions caused by leaking. The red dye leak identifier mentioned above may be used in future systems to pinpoint leaks that currently go undetected.

Recovery and recycle of CFCs at product disposal is not economical for chillers alone. However, Rand suggests that recovery in conjunction with mobile air conditioners may be possible.[25]

4. Direct Contact Freezing Agent

CFC-12 is used as a freezing agent in approximately 30 liquid fast freezing (LFF) systems. Products such as fruits, vegetables, seafood, and meats come in direct contact with CFCs in the LFF process. In 1977, 6.5 million pounds of CFC-12 were

used and emitted to the atmosphere. The market is likely to expand rapidly through 1985 when CFC-12 use may reach as high as 18 million pounds annually.

However, the rising cost of CFC-12 has already stimulated the development of conservation measures. Since this liquid fast freezing technology is fairly new, it is possible that further technological developments such as improved condensers can maintain emissions at a constant level of about 6.5 million pounds while the frozen food output expands. There are close, although less desirable, substitute processes for LFF.

5. Diluent Gas In Gas Sterilizing Applications

CFC-12 is mixed with ethylene oxide (EO) to form sterilizing gas used in hospital and industrial gas sterilizing applications. Pure EO can be used as sterilizing gas, but it is highly toxic, flammable, and explosive.[32] In 1976 between 11 and 14 million pounds of CFC-12 were used to dilute EO to a mixture known as 88/12, consisting of 88 percent CFC-12 and 12 percent EO. These CFCs are generally emitted directly to the atmosphere from the sterilizing units following use. Approximately 200 large industrial sterilization units account for 75 to 80 percent of the CFC used as diluent gas. The remainder is used in smaller hospital units. Both the large and small units supply hospitals with sterilized equipment.

Rand predicts growth in the use of CFC-12 for this purpose. Carbon dioxide (CO_2) may be substituted for CFC-12, but switchover costs would be very high because equipment designed for the CFC/EO mixture cannot handle a CO_2/EO mixture. Because of increased CFC costs, manufacturers of industrial sterilizers have shown considerable interest in recycling used 88/12. Further investigation is required to determine the level of emissions reduction attainable through recovery and recycle.

6. Active Agent In Fire Extinguishing Applications

FC-13B1 (Halon 1301), a bromine compound, is used in "total flooding" fire extinguishing systems. Rand estimates that in 1977, 1.5 to 3.0 million pounds of Halon 1301 were used in fire extinguishing applications with emissions occurring during testing, servicing, and use. In 1977 Halon 1301 emissions are estimated to have been under 1.0 million pounds.[33] By 1990 emissions are not likely to be greater than 2.0 million pounds annually.[33] Despite the small quantity of emissions, Halon 1301 may also contribute to the depletion of the ozone layer.[33] Research is underway to evaluate the atmospheric chemistry of bromine compounds and their potential effect on the ozone layer.

There are approximately 10,000 "total flooding" systems today, with approximately 80 percent of those installed in spaces containing electronic equipment such as computers and other microcircuit equipment. It is difficult to estimate the amount of Halon 1301 banked because little is known about the average charge per system. Rand predicts that the amount of Halon 1301 banked in total flooding fire extinguishing systems will grow from 6 million pounds in 1976 to approximately 30 million pounds in 1990. DuPont states that Halon 1301 is the only compound which can be used safely at the concentrations required to extinguish a fire in a confined space.[29]

Rand reports that because of the high cost of Halon 1301, manufacturers are attempting to limit emissions.[26] Further investigation is required to determine possible emission reduction strategies that do not compromise adequate fire protection.

7. Miscellaneous Uses

EPA is currently evaluating numerous miscellaneous products that use small amounts of CFCs. The estimates for the total annual use of CFCs in such products range from several thousand to over a million pounds per year.

Included in this category are those aerosol products not covered by the ban on the manufacture and processing of CFCs as propellants for aerosol products. EPA's rule defines an aerosol propellant as a substance that expels a substance different from itself from a container. Aerosol products such as the pressurized blower that contain only CFCs are exempt from the CFC rule, but are currently under investigation. The information below is based on the Rand's preliminary analysis of miscellaneous uses.[34] Investigation is continuing on this category of products to develop more detailed information.

a) Warning devices

Warning devices are those products which use CFCs to sound an alarm. This category includes devices which can be divided into prompt emitting products and nonprompt emitting products. The single-station heat detector is a nonprompt emitting product since it may sit idle many years before discharging. Intruder alarms, boat horns and bicycle horns are considered prompt emitters. In all types of warning devices a chlorofluorocarbon, generally CFC-12, is released by a detector mechanism through a horn.

The warning device industry uses an estimated 1.5 million pounds of CFCs per year. Roughly 5000 pounds of CFCs were emitted in 1975 for heat detectors alone. Projected emissions for heat detectors in 1990 may be as high as 90,000 pounds.

b) Pressurized Blowers and Drain Cleaners

Products from this category emit approximately 1 million pounds of CFCs per year. Emissions are projected to double by 1990.

Pressurized blowers are used to blow dust from photographic work, electronic equipment, lenses, graphics work, and art work. CFC-11 is commonly used as the propellant. Carbon dioxide, nitrogen and compressed air have been mentioned as

possible substitutes; however, more study is needed to determine the effectiveness of these substitutes.

Drain cleaners primarily use CFC-12. CFC-114 is also used in drain cleaners, but to a lesser extent. Hydrocarbons can be substituted for the CFCs; however, the higher flammability of hydrocarbons may make them a less desirable alternative for CFCs. Although lye is used as a drain cleaner, the consumer faces considerable danger during normal use.

c) Coal Cleaning

Interest in the research and development of using CFCs to clean coal is growing. Newly developed coal cleaning processes use CFC-11 and may be more efficient and less costly than currently employed coal cleaning techniques. Coal cleaning processes which use CFCs reduce the sulfur and ash emissions from coal incineration. The energy value (BTUs) per pound of CFC-treated coal is greater than untreated coal or hydro-treated coal.[36]

Because the CFC coal cleaning processes are totally enclosed, emissions are limited to leaks from mechanical seals, air streams and residues on the products. As a pollution control measure in the incineration of coal, coal cleaning could become a major source of CFC emissions by 1990. One company estimates that annual emissions could be as high as 3.5 million pounds by 1989.

d) Presurgical Skin Cleaner and Skin Chilling

In 1976, presurgical skin cleaners used 100,000 pounds of CFC-113. Small amounts of CFC-113 are also used as a coolant to relieve myofascial pain and muscle spasm, to freeze skin for surgery, and to topically anesthetize patients. Applied to the surface of the skin, CFCs evaporate immediately; thus, these products are considered prompt emitters.

e) Whipped Topping Stabilizer

CFC-115 is used as a stabilizer for whipped toppings in spray cans. Approximately 100,000 pounds are used for this purpose annually. Market growth historically has been 2 to 4 percent annually; however, a market decline attributable to concern over possible regulation has been observed.

Research continues on substitutes. At this time, no chemicals appear as effective as CFC-115 in stabilizing whipped toppings.

f) Other Miscellaneous Uses

There are other miscellaneous products, such as those listed below. This list is not meant to be exhaustive, since there may be uses of CFCs of which we are not aware.

-aerosol chiller for isolating defective electronic parts.

-drying system in numismatic blanks, coins, and medals.

-dielectric fluid in transformers.

-cleaner and preserver for printed material, films and phonographic recordings at the Library of Congress.

-coolant in the uranium enrichment process of nuclear power plants.

B. Regulatory Options

The two parts of regulatory pollution control are determining the level of emission reduction sufficient to protect human health and the environment, and defining and implementing the least cost method of achieving emission reduction. To define the best method for reducing emissions, EPA is examining three

regulatory options: 1) direct regulation; 2) economic incentive approaches; and 3) a conservation program. These options are not mutually exclusive and could be used in combination to maximize net social benefit. The choice of a regulatory strategy will be based on, but not limited to, the following criteria: the certainty of achieving emission goals; the cost of control; the ease of implementation; equity; the amount of information required to promulgate and enforce the regulation; and administrative costs. The following is a description of the various strategies.

1. Direct Regulation

Until now, EPA has used three basic forms of direct regulation: 1) technology requirements, where EPA requires the use of specific equipment or processes; 2) emission standards, where EPA limits the concentration or amount of certain pollutants released into the environment; and 3) banning a substance for a certain use.

As an example of a technology requirement, EPA must approve the process used to incinerate polychlorinated biphenyls (PCBs). One characteristic of technology requirements, and direct regulation in general, is that different requirements can be developed for different industries that use the same substance. For example, industries with very low emission control costs could be required to adopt a process or technology that eliminates a large percentage of their emissions. At the same time, industries with high emission control costs could be required to reduce emissions only a small amount. Although this strategy may reduce emissions to a specified level at minimum control cost, it may not be perceived as equitable.

Emission standards are a less restrictive form of regulation than technology requirements for industry production processes. Emission standards allow firms to adopt their own least cost methods of achieving the required level of emission reduction. For example, if industries were required to reduce emissions by

20 percent in a specified amount of time, they would have the freedom to use what they considered to be the best control technologies. Industry initiated control strategies may be desirable when EPA has less information about control technologies than does industry. However, emission standards could be more difficult to enforce than technology requirements, because surveillance of emissions is often more complicated than surveillance of technologies or equipment.

The final form of direct regulation is product limitation, use restrictions, or ban. As noted in the previous chapter, the ban approach was used to limit aerosol uses of CFCs. Aerosol uses of CFCs were banned because the hazards posed by continued use greatly outweighed the costs of eliminating the emissions. Substitutes were available that did not pose risks to human health or the environment, and the costs were minor. This is a good example of direct regulation being applied to only a portion of the uses of a particular substance.

Unlike most stationary source pollution problems, the majority of CFC emissions occur during the normal use and disposal stages of a product's life rather than during its more centralized production stage. For example, CFC emissions from rigid insulating foams in buildings are so small and occur incrementally over long periods of time that it would be very difficult to regulate the hundreds of thousands of buildings that contain such insulation. Similarly, CFC emissions from mobile air conditioners could be reduced by as much as 23 million pounds in 1990 if improved servicing procedures were used. However, mobile air conditioners are serviced at approximately 140,000 locations nationwide, thus making specific service and maintenance standards virtually impossible to enforce. Although other options are being investigated, EPA will continue to study combinations of the various types of direct regulation if CFC emissions must be reduced.

2. Economic Incentive Approaches

An alternative to direct regulation is an economic incentive approach to pollution control. Economic theory defines a pollution problem as existing when the cost of producing a good does not include the social cost of environmental damage caused by its production. For example, it may require $10 of inputs to produce one unit of a good. The pollution emitted during production may cause $4 worth of damage to the environment. Without controls, the total cost of producing the good would be perceived by the firm as being $10 instead of the actual $10 + $4= $14. The extra $4 of environmental costs, referred to as "externalities", would be borne by the general public in terms of reduced environmental quality or increased health hazard.

If these environmental costs, or externalities, could be internalized into the firm's production costs, then the firm would seek to reduce emissions as part of its overall goal of cost minimization. The cost of the remaining environmental damage would then be borne by those who enjoy the benefits of the good through a higher product price. In addition, this economic approach could reduce EPA's cost of administration and enforcement. Once environmental damage costs are internalized into production costs, individual profit maximizing firms will reduce emissions as long as marginal emission reduction costs are less than marginal environmental damage costs. Therefore, this economic incentive of internalized environmental costs would necessarily lead to emission reduction.

EPA is currently investigating two economic approaches, use fees and marketable permits. Each is discussed in more detail below.

a) Use Fees

Use fee systems have been discussed extensively in the economics literature. EPA could incorporate the cost of

environmental damage into a firm's production costs as discussed above, by instituting a fee for using or emitting a unit of the substance that causes the environmental damage. If a payment of $4 was required in order to emit the pollution resulting from the production of each unit of good in the example above, then the perceived cost of production would be equal to the true total cost of $14. The firm could reduce production costs by reducing emissions. If the firm were to reduce emissions by 50 percent at a cost of $1, the resulting production costs would be $10 for inputs, a $2 fee for emitting 50 percent of the original level of pollution, and $1 emission control costs, for a total production cost of $13. Since this is a net reduction in production cost, an individual profit maximizing firm would have incentive to adopt the emission controls under the use fee system.

In the case of CFCs, all the CFCs used in a process are eventually emitted. Therefore, rather than impose a fee on CFC emissions, which could be difficult to monitor, a fee could be imposed on CFC use. Since the health and environmental damage from CFC emissions does not depend on the source, a single per pound fee for CFC use would be appropriate. This implicitly assumes a zero discount rate for the effects of future emissions from the existing CFC bank.

One major problem with instituting a use fee is its computation. The optimal use of a chemical is defined by the point at which the marginal social value of chemical use associated with emissions equals the marginal cost of production plus the marginal environmental costs or externalities. The correct tax would be the value of the marginal environmental damage caused by the chemical emissions. Since it is very difficult to estimate the value of environmental quality, direct computation of the fee would be impossible. If a required level of emission reduction could be identified, the use fee necessary to achieve that reduction could be estimated from an analysis of all the elasticities of demand for CFCs. Since this analysis may be prohibitive, an iterative approach to setting the fee could be

used; depending on the resulting emission reduction, the fee could be adjusted up or down. However, some business leaders claim that rapidly changing use fees would complicate investment and other business decisions because of added uncertainity of the market.[37]

Currently EPA does not impose use fees. There are many legal questions that must be addressed before use fees could be employed as a means of controlling emissions. This strategy needs to be studied further.

b) Marketable Permits

A use fee system would not set a limit on chemical use. Instead, a fee would only be an economic incentive to reduce emissions. Firms would be free to use as much CFCs as they like so long as the fees were paid. A marketable permit system would take the opposite approach. EPA would set a rigid quota, and firms would bid for the rights or permits to a portion of that quota. The permits would have a positive economic value so long as the quota was set below whatever demand would have been in the absence of regulation.

Unlike the use fee system that would set a single price for CFC usage, the price of a marketable permit would be determined on the open market. The final equilibrium price of the permit would primarily depend on 1) the stringency of the quota in the short run; 2) the ability of firms to reduce CFC usage at a per unit cost below the unit cost of the permit; and 3) final demand for products that require CFCs.

The advantage of using a marketable permit approach to allocate a quota is that it allows the market to determine which uses of CFCs are most highly valued or "essential". As the permits are traded, the producers of those products for which there are no substitutes will be willing to pay more for the permits in order to get their needed CFCs. As the price of the permits increases, industry will stop manufacturing nonessential

products, adopt substitutes for other products, and employ emission controls and recovery measures where possible in order to minimize use of CFCs. In the long run the permits will be distributed among those firms that place highest value on their use.

There are several basic questions which must be resolved before a marketable permit strategy could be implemented. EPA must decide how to allocate the permits. They could be distributed either by direct sale to the highest bidder in a central market or auction, or by allocation to current CFC users as a function of past usage. The choice between these strategies would not affect the ultimate equilibrium price of the permits. The two initial distribution methods will, however, have different effects on the redistribution of wealth that may result from a marketable permit system. If the permits were auctioned off, wealth would be transferred to the government from industry. The large firms may be able to outbid the small firms, thus preventing small businesses from using CFCs. If the permits were allocated based on past use, wealth would be transferred among firms as the permits were traded. One problem with allocation based on past use is that it prevents new and potentially highly valued uses of CFCs from being allocated permits. New CFC users would have to buy permits from existing users who receive them automatically. The two permit distribution methods could also be used in combination. For example, 80 percent of the permits could be sold at auction to the highest bidders, while 20 percent of the permits could be allocated or sold at a predetermined price to small businesses.

In addition to the question of initial permit allocation, there is the problem of tracking "prompt" versus "nonprompt" emissions. Since marketable permits apply to CFC use, and not CFC emission, a method must be devised to keep track of how much of a year's quota is placed in nonprompt emitting products (the CFC bank). In order to keep future annual emissions under a certain level, the estimate of total emissions must include

emissions from the CFC bank. For example, if the maximum acceptable annual emissions were 100 pounds, and previous use information indicated that CFC inventory emissions would be 20 pounds, then the emissions quota for that year would have to be at most 80 pounds. How best to address these and other issues is currently under investigation.

3. Conservation Program

Depending upon its assessment of all the pertinent scientific, economic, and technological factors from all sources, including the industry, EPA could decide to defer further regulation until additional research and other studies were completed. In that case, EPA most likely would adopt a conservation program for reducing CFC emissions and promoting research in the area of ozone depletion. Relying on voluntary cooperation and compliance from industry, this program would concentrate on limiting the market growth of new applications of CFC uses, particularly where new uses may not be essential.

It has been noted that both the academic community and industry are devoting considerable resources to research the uses and environmental impacts of CFCs. EPA could serve as a clearinghouse to collect and disseminate the information on methods for reducing CFC emissions from various uses. EPA could participate with industry and academia in defining research needs and funding essential projects. EPA could negotiate voluntary emission reduction goals (e.g., 20 percent by 1985) and monitor uses, emissions, and the development of emission control technologies to help meet the emission reduction goals. By instituting a conservation program along the lines described, EPA would

1. advance its knowledge of uses and emissions of CFCs,

2. begin to reduce CFC emissions by promoting new emission reduction technologies, and

3. promote state-of-the-art advances in analyzing the effect of CFC emissions on the ozone layer.

To date some segments of industry have been very receptive to these types of initiatives. Continued industrial cooperation plus detailed planning would be needed before this program could be implemented effectively.

C. Risk Assessment

One of the key evaluations necessary in the regulatory decision making process is an assessment of the environmental and health risks associated with continued use of CFCs. This risk assessment must take into account the potential magnitude of CFC release, the effects on stratospheric ozone, and the resulting effects on health and the environment.

Based on historical emission rates as well as projections through 1990,[25] EPA has developed emission rate profiles through 1990 for each CFC in commercial use, and for the various regulatory options under consideration. These options include unrestrained growth, a conservation program, technological controls and a total ban on CFCs. Emission rate profiles are vital input into model predictions of ozone depletion.

Once ozone depletion rates are developed, estimates of increases in biologically harmful ultraviolet radiation reaching the earth's surface can be made. The results of laboratory and epidemiological studies should provide a reasonable basis to conclude that exposure to this radiation increases the risk of skin cancer in humans. EPA will also qualitatively assess the potential effects of alterations in the levels of ozone on climate and biota.

Several reports are essential to the completion of the risk assessment. The Rand Corporation report provides information on the nonaerosol CFC industries and their emission rate profiles. A draft final report is expected from the Rand Corporation in the Fall of this year this summer. SRI International, using Rand's emission rates, is analyzing available control options from a cost/benefit point of view. A general cost/benefit analysis also is the focus of the University of Maryland report. The two latter reports will be submitted to EPA's Office of Research and Development in the early Fall.

As required in Section 153 of the CAA, the National Academy of Sciences has the responsibility of reviewing the state-of-knowledge of atmospheric physics and chemistry, the health effects, environmental effects, and alternative control measures associated with stratospheric ozone depletion. The NAS report on atmospheric physics and chemistry should be available in September; the other studies will follow shortly thereafter. Data from these studies will provide additional input to the risk assessment. The EPA estimates of CFC emission reductions resulting from various control scenarios should be available by the end of the year.

III INTERNATIONAL COOPERATION

The first international regulatory meeting on chlorofluoromethanes or CFCs, held from April 26-28, 1977, in Washington, DC, sponsored by the Department of State, EPA, FDA, and CPSC was discussed in the first report to Congress. A second meeting was held on December 6-8, 1978 in Munich, Germany. This international conference on CFCs was attended by representatives from Australia, Belgium, Canada, Denmark, France, Federal Republic of Germany, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom, United States, Yugoslavia, the European Community Commission (ECC), the OECD Environment Committee, and the United Nations Environment Program (UNEP). As before, these countries met to share information on the state of knowledge about CFCs and their effect on health and the environment. One of the major conference objectives was to determine what future actions could be taken by these countries to mitigate harmful effects.

UNEP's Coordinating Committee on the Ozone Layer (CCOL) met in Bonn, Germany from November 28-30, 1978 to assess stratospheric ozone depletion and its resulting effects on life on earth, and to provide a scientific basis for the international regulatory meeting in Munich. Experts from Australia, Canada, France, Federal Republic of Germany, Netherlands, Norway, United Kingdom, United States, UNEP, World Health Organization (WHO), World Meteorological Organization (WMO), International Council of Scientific Unions, Chemical Manufacturers Association, and the European Economic Community (EEC) attended the meeting.

The CCOL reviewed the latest reports on stratospheric ozone depletion, including the October 1978 World Meteorological Organization (WMO) statement on the modification of the ozone layer caused by human activity. CCOL essentially agreed with WMO and noted that while there are still large uncertainties in both the predicted ozone depletion and the consequences of ozone depletion a relatively consistent picture of the effects of human activity on stratospheric ozone is emerging.

Based on global research and monitoring, the WMO noted that there is evidence to support the theory that continued CFC release into the atmosphere would cause ozone depletion.[38] Continued CFC releases at 1975 levels (750 metric tons) would eventually lead to an estimated steady state ozone reduction of 15 percent and about a 30 percent increase in ultraviolet radiation in the 280-320 nanometers wavelength range.

CCOL concluded that it was possible to correlate latitude to skin cancer incidence, even though correlation of the incidence of skin cancer malignancy with solar UV levels had not yet been made with great accuracy.[6] White-skinned populations are susceptible to skin cancers believed to be caused by solar UV-B radiation.[6] In addition, UV-B radiation is potentially detrimental to certain plant species. Aquatic species living near the surface waters are also very suspectible to UV-B.[6] Even though impacts on changes in climate in the ozone layer are considered to be small, stratospheric temperature changes may eventually be as large as 5 to 10 degrees centigrade.[6] Such changes could lead to structural modification in the atmospheric planetary-scale waves, with consequent effects on storm tracks and regional climates.[6]

EPA headed the United States delegation to the international regulatory meeting in Munich which included representatives from FDA, CPSC, and the State Department. With the background of U.S. research data, UNEP and WMO statements, and other information, the U.S. delegation attempted to convince the representatives of the CFC producing and consuming countries that a substantial reduction of CFCs in aerosol products is low cost insurance against the risk of stratospheric ozone depletion. The Deputy Administrator of EPA in her speech to the conference pointed out that if there are no additional restrictions on global releases of CFCs, worldwide emissions could reach 1975 levels within 10 years, thereby offsetting U.S. action regulating CFCs as aerosol propellants. The Deputy Administrator believed that, "there was only one course of action open: a unified global approach to

dealing with the health and environmental risks associated with CFC production and use. Multilateral and unilateral support for worldwide reduction of aerosol emissions must come from the European communities and international organizations, as well as from those of us who have already taken some form of action on this problem."[39] Other U.S. speakers pointed out that investigations into the nonaerosol uses of chlorofluorocarbons have shown that it will probably cost the American economy more to take action against the U.S. nonaerosol products than it will cost the economies of other nations to take action against worldwide nonessential aerosol products.

Although quantitative commitments were not agreed upon, all countries did agree to make significant reductions in aerosol use from 1975 levels. The participants agreed further that if new evidence to substantiate the ozone depletion theory were forthcoming, they would undertake further reductions. In addition, the conference members acknowledged the need to continue research in atmospheric chemistry and physics and related scientific areas, in order to broaden the scientific knowledge of the hazards to the ozone layer by continued use of CFCs. They noted that additional study is also required to better estimate the effects of increased ultraviolet radiation on world population, vegetation, and ecosystems. The members also recommended continued research on potential substitutes for CFCs, on control techniques to reduce CFC emissions, and on the economics of regulatory and non-regulatory actions.

The discussions that occurred during this two-day conference produced two bodies of opinion on the preferred way to achieve CFC reduction. Some countries favored voluntary agreements with industry, as opposed to the usual regulatory approach. Some countries reported taking action; others reported no action, with a few unsure about what to do, if anything.

The United States, United Kingdom, France, Germany, Italy and Japan account for more than 90 percent of the world

production of CFCs. As of July 1979 the United States and Sweden have taken regulatory action banning CFCs as aerosol propellants.[9,10,40] Canada will follow suit in December 1979.[41] The Netherlands has published a law requiring that all aerosol products containing CFCs be so labelled.[42] In addition, the Netherlands has concluded that a banning regulation may be necessary, but is waiting to see what action is taken by the European Economic Community and other countries. Norway anticipates that by 1981 regulations are likely to reduce emissions by 50 percent.[43]

The nine members of the EEC are expected to act jointly in accordance with the council decision proposed in May 1979 which would require the member countries to

1. not increase CFC capacity,
2. reduce CFCs in aerosols by 30 percent by January 1982 based on 1976 levels,
3. report on the effectiveness of controls early in 1982, and
4. consider the Commission's proposals for further measures later in 1982.[44]

Several countries have reported voluntary reduction agreements with their industry. Under an agreement with the aerosol industry associations in Germany and Switzerland, each country will reduce CFC use in aerosols by 30 percent by 1979; in Denmark CFC had already been reduced by 24 percent in 1978.[43]

There appear to be more countries who are undecided about taking any action than countries who have taken some action. Nevertheless, EPA and other regulatory agencies will continue to work with the international community to stress that emissions of substances harmful to the ozone layer is a global problem and that a multilateral approach to protecting the stratosphere is essential to our mutual wellbeing.

IV INVESTIGATION OF OTHER STRATOSPHERIC OZONE DEPLETING SUBSTANCES

CFCs are not the only possible ozone depleting materials under scientific investigation. EPA is investigating other chemical substances such as methyl chloroform, nitrous oxide, and carbon tetrachloride for ozone depletion potential. Monitoring programs also have been established to quantify the ozone depleting potential of several suspected substances.

OTS and the Office of Research and Development (ORD) are assessing the risk associated with methyl chloroform. At the request of the Office of Air Quality Planning and Standards (OAQPS), the risk assessment will study the long-term effects of methyl chloroform as an ozone depleting compound. This risk assessment will provide a scientific basis for implementing or not implementing a standard proposed by OAQPS which would remove methyl chloroform from the list of chemicals exempt from air quality standards.

A preliminary analysis of nitrous oxide has been prepared which includes a materials balance.[45] The nitrous oxide report concludes that the problem could be serious in 20 to 50 years, but it is not an immediate crisis. The report recommends more accurate analyses on estimated global emission change in nitrous oxide from soil, fertilizer, and crop systems and on the amounts of nitrous oxide concentration changing in the atmosphere.

Except for CFC-11 and CFC-12, global data for stratospheric ozone depleting materials have not been collected in any centralized or systematic way. Strengthening the data base is a major goal of the current OTS monitoring program for other ozone depleting emissions. Methylene chloride, CFC-22, and nitrous oxide are currently the subjects of such monitoring studies.

Materials balances and studies to trace the fate of chemicals through the atmospheric system will provide initial steps in the ozone depletion analysis. For example, a materials

balance of methyl chloroform and carbon tetrachloride is currently being developed. Once sources of the chemical are identified by the general materials balance, emissions data can be collected on an annual basis. Annual materials balances are planned by OTS in the near future for other potential stratospheric ozone depleters.

OTS has developed an interagency agreement with the National Oceanic and Atmospheric Administration (NOAA). Under this agreement, NOAA will organize a workshop in late September that will focus on methodologies for screening chemicals for stratospheric ozone depletion potential. OTS expects the methodology to be integrated into risk assessment procedures for the premanufacturing review of new chemicals required by Section 5 of TSCA. Moreover, OTS will recommend to the Interagency Testing Committee that their ranking of existing chemicals include consideration of potential to adversely modify the stratosphere. OTS is also developing a methodology for identifying chemical substances that may have potential for affecting the radiative transfer balance of the atmosphere.

The Stratospheric Impact Research and Assessment (SIRA) Program of the EPA Office of Research and Development has the responsibility under Section 153 of the CAA to study human causes of stratospheric ozone depletion, its effects on public health and welfare, and alternative methods for regulation. This study includes the effects on human health and terrestrial and aquatic ecosystems of ultraviolet radiation associated with ozone depletion, and climatic effects research associated with changes in penetrating ultraviolet radiation. Monitoring UV radiation, developing instrumentation to measure UV radiation, and analyzing socioeconomic effects of UV radiation on health and the environment are also important program considerations. The progress of EPA's research program will be reported to Congress on or before January 1, 1980, as required under Section 153(g) of the CAA.

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